MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2017/2018

EEL1176 – FIELD THEORY

(All sections / Groups)

21 OCTOBER 2017
2.30 p.m - 4.30 p.m
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This question paper consists of 8 pages with 4 questions only.

2. Answer all **FOUR** questions. All questions carry equal marks and the distribution of the marks for each question is given.

3. Please write all your answers in the Answer Booklet provided.

Question 1 (25 marks)

(a) Given vectors $\vec{A} = \hat{x} + \hat{y} + 3\hat{z}$, $\vec{B} = \hat{x} + 2\hat{y} + \hat{z}$ and $\vec{C} = 3\hat{x} + \hat{y} + 2\hat{z}$. Find

(i) $\vec{A} \bullet (\vec{B} \times \vec{C})$ [2 marks]

(ii) $\vec{A} \times (\vec{B} \times \vec{C})$ [3 marks]

(iii) $(\vec{A} \times \hat{y}) \bullet \hat{z}$ [2 marks]

(a) Given vectors $\vec{A} = \hat{x} + \hat{y} + 3\hat{z}$, $\vec{B} = \hat{x} + 2\hat{y} + \hat{z}$ and $\vec{C} = 3\hat{x} + \hat{y} + 2\hat{z}$. Find

(i)

(b) Convert the Cartesian coordinates of $P(-4, 4, -4)$ to the following coordinates.

(i) Cylindrical Coordinates [1.5 marks]
(ii) Spherical Coordinates. [1.5 marks]

(c) A structure with the following dimensions are provided: $r = 4$; $30° \le \phi \le 60°$; $0 \le z \le 6$.

(i) Sketch the outline of the cylindrical surface [3marks]

(ii) Determine the total surface area by performing surface integral. [4 marks]

(d) Given the vector field and $\oiint_S E \cdot d\mathbf{s} =$ —— through a closed surface of a cylinder defined by , and .

Verify the divergence theorem $\iiint_v \nabla \cdot E dv = \oiint_S E \cdot d\mathbf{s}$. [8marks]

Continued ...

Question 2 (25 marks)

(a) Point charges of 3μC, 2μC and 5μC are located in free spaces at (2, -1, 5), (-3, 2,1) and (0, 2, 0), respectively.

(i) Find electric field intensity, E on a charge located at (0, 2, 1).

[6 marks]

(ii) Find the electrical force on a 10nC charge at the same points (0, 2, 1).

[3 marks]

(b) An infinitely long wire carries charge density, ρ_l C/m, lying along the x- axis, as illustrated in **Figure 1**. Determine the electric field intensity, **E** at point P = (0, y, 0) located at a distance y from the center of the wire using Gauss law.

[8 marks]

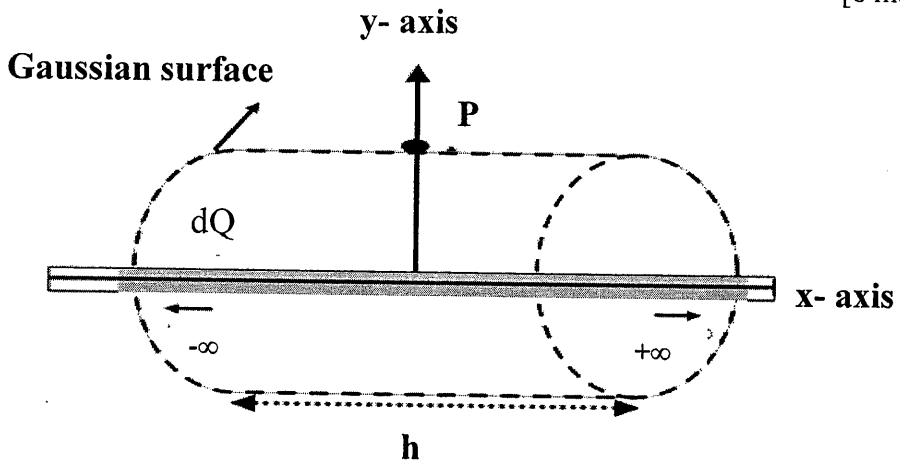

Figure 1

(c) A spherical capacitor is constructed of two concentric sphere of metal with radius of R_1 = 3m and R_2 = 8m. The space between the conductors is filled with two dielectrics, which are bakelite with dielectric constant, ε_1 = 5 occupies one hemisphere while the second dielectric with mica, dielectric constant, ε_r = 6 occupies the other hemisphere as shown in **Figure 2**. Determine the capacitance for the configuration.

[8 marks]

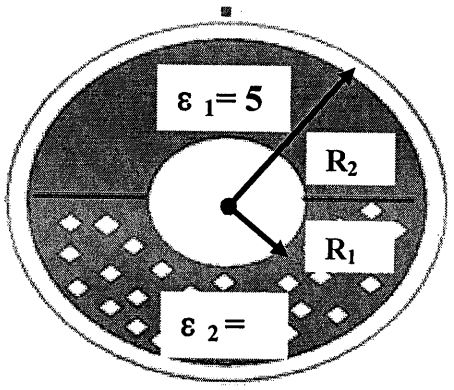

Figure 2

Continued..

Question 3 (25 marks)

(a) (i) Briefly explain the main difference between magnetic field and magnetic flux. [2 marks]

(ii) List down 4 characteristics of lines of magnetic flux. [4 marks]

(b) (i) Briefly describe the differences between electric and magnetic forces. [2 marks]

(ii) A charge 1.8×10^{-19} C is moving with a speed of 1×10^{6} m/s through a magnetic field. The magnetic flux density with 3.5 T experiences a magnetic force of magnitude 2×10^{-13} N. Determine the angle between the magnetic field and proton's velocity? [6 marks]

(iii) Apply the Amperes Law to case-(I) and case-(II) in Figure 3(c) qualitatively, or without vigorous mathematical derivation.

[2+2 marks]

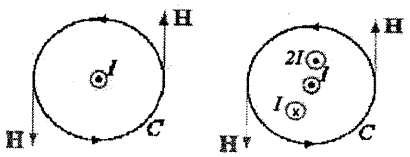

Figure 3(c): case-(I) case-(II)

(c) (i) Define what is electromagnetic induction ? [2 marks]

(ii) A circular Ultra High Frequency (UHF) television antenna has a diameter of 11 cm. The magnetic field of a TV signal is normal to the plane of the loop and, at one instant of time, its magnitude is changing at the rate of 0.16 T/s. The field is uniform. What is the emf in the antenna ?

[5 marks]

Continued..

Question 4 (25 marks)

(a) Draw a hysterisis loop for ferromagnetic material. With proper axis label. [3 marks]

Label the following on the hysteresis loop in part (a):

(i) Saturation [1 mark]
(ii) Retentivity [1 mark]
(iii) Coercivity [1 mark]
(iv) Saturation in opposite in negative direction [1 mark]
(v) Retentivity in opposite in negative direction [1 mark]
(vi) Coercivity in opposite in pisitive direction [1 mark]

(b) A circular cross section ring made from magnetic material. The ring has a mean radius 12 cm and thickness of 1 cm. An air gap of 1 mm length is cut across the ring. The ring is wound with 1000 turns of wire carrying a current of 2 A, producing 1 T of flux density in the air gap.

Assume no fringing effect and no flux leakage, calculate:
(i) Magnetic field intensity, H in the magnetic material. [6 marks]
(ii) Relative permeability, μ_r of the magnetic material. [3 marks]
(iii) Total reluctance, R_T of the magnetic circuit. [7 marks]

Continued..

Appendix A: Physical Constants, Vector and Coordinate Transformations

Elementary charge	e	1.60×10^{-19} C
Permittivity of free space	ε_0	8.85×10^{-12} F/m
Permeability of free space	μ_0	1.26×10^{-6} H/m $= 4\pi \times 10^{-7}$ H/m

	Cartesian Coordinates	Cylindrical Coordinates	Spherical Coordinates
Differential length	$\hat{x}dx + \hat{y}dy + \hat{z}dz$	$\hat{r}dr + \hat{\phi}\, r\, d\phi + \hat{z}dz$	$\hat{R}dR + \hat{\theta}Rd\theta + \hat{\phi}R\sin\theta d\phi$
Differential surface areas	$d\vec{s}_x = \hat{x}\, dydz$ $d\vec{s}_y = \hat{y}\, dxdz$ $d\vec{s}_z = \hat{z}\, dxdy$	$d\vec{s}_r = \hat{r}\, rd\phi\, dz$ $d\vec{s}_\phi = \hat{\phi}\, dr\, dz$ $d\vec{s}_z = \hat{z}\, rdr\, d\phi$	$d\vec{s}_R = \hat{R}\, R^2 \sin\theta\, d\theta\, d\phi$ $d\vec{s}_\theta = \hat{\theta}\, R\sin\theta\, dR\, d\phi$ $d\vec{s}_\phi = \hat{\phi}\, R\, dR\, d\theta$
Differential volume	$dx\, dy\, dz$	$dr\, d\phi\, dz$	$dR\, R\, d\theta\, R\sin\theta\, d\phi$

Transformation	Coordinate Variables	Unit Vectors	Vector Components
Cartesian & Cylindrical	$r = \sqrt{x^2 + y^2}$ $\phi = \tan^{-1}(y/x)$ $z = z$	$\hat{r} = \hat{x}\cos\phi + \hat{y}\sin\phi$ $\hat{\phi} = -\hat{x}\sin\phi + \hat{y}\cos\phi$ $\hat{z} = \hat{z}$	$A_r = A_x\cos\phi + A_y\sin\phi$ $A_\phi = -A_x\sin\phi + A_y\cos\phi$ $A_z = A_z$
	$x = r\cos\phi$ $y = r\sin\phi$ $z = z$	$\hat{x} = \hat{r}\cos\phi - \hat{\phi}\sin\phi$ $\hat{y} = \hat{r}\sin\phi + \hat{\phi}\cos\phi$ $\hat{z} = \hat{z}$	$A_x = A_r\cos\phi - A_\phi\sin\phi$ $A_y = A_r\sin\phi + A_\phi\cos\phi$ $A_z = A_z$
Spherical & Cartesian	$R = \sqrt{x^2 + y^2 + z^2}$ $\theta = \tan^{-1}(\sqrt{x^2 + y^2}/z)$ $\phi = \tan^{-1}(y/x)$	$\hat{R} = \hat{x}\sin\theta\cos\phi + \hat{y}\sin\theta\sin\phi + \hat{z}\cos\theta$ $\hat{\theta} = \hat{x}\cos\theta\cos\phi + \hat{y}\cos\theta\sin\phi - \hat{z}\sin\theta$ $\hat{\phi} = -\hat{x}\sin\phi + \hat{y}\cos\phi$	$A_R = A_x\sin\theta\cos\phi + A_y\sin\theta\sin\phi + A_z\cos\theta$ $A_\theta = A_x\cos\theta\cos\phi + A_y\cos\theta\sin\phi - A_z\sin\theta$ $A_\phi = -A_x\sin\phi + A_y\cos\phi$
	$x = R\sin\theta\cos\phi$ $y = R\sin\theta\sin\phi$ $z = R\cos\theta$	$\hat{x} = \hat{R}\sin\theta\cos\phi + \hat{\theta}\cos\theta\cos\phi - \hat{\phi}\sin\phi$ $\hat{y} = \hat{R}\sin\theta\sin\phi + \hat{\theta}\cos\theta\sin\phi + \hat{\phi}\cos\phi$ $\hat{z} = \hat{R}\cos\theta - \hat{\theta}\sin\theta$	$A_x = A_R\sin\theta\cos\phi + A_\theta\cos\theta\cos\phi - A_\phi\sin\phi$ $A_y = A_R\sin\theta\sin\phi + A_\theta\cos\theta\sin\phi + A_\phi\cos\phi$ $A_z = A_R\cos\theta - A_\theta\sin\theta$
Cylindrical & Spherical	$R = \sqrt{r^2 + z^2}$ $\theta = \tan^{-1}(r/z)$ $\phi = \phi$	$\hat{R} = \hat{r}\sin\theta + \hat{z}\cos\theta$ $\hat{\theta} = \hat{r}\cos\theta - \hat{z}\sin\theta$ $\hat{\phi} = \hat{\phi}$	$A_R = A_r\sin\theta + A_z\cos\theta$ $A_\theta = A_r\cos\theta - A_z\sin\theta$ $A_\phi = A_\phi$
	$r = R\sin\theta$ $\phi = \phi$ $z = R\cos\theta$	$\hat{r} = \hat{R}\sin\theta + \hat{\theta}\cos\theta$ $\hat{\phi} = \hat{\phi}$ $\hat{z} = \hat{R}\cos\theta - \hat{\theta}\sin\theta$	$A_r = A_R\sin\theta + A_\theta\cos\theta$ $A_\phi = A_\phi$ $A_z = A_R\cos\theta - A_\theta\sin\theta$

Appendix B: Gradient, Divergence, Curl and Laplacian Operators

Cartesian coordinate (x, y, z)

$$\nabla V = \hat{x}\frac{\partial V}{\partial x} + \hat{y}\frac{\partial V}{\partial y} + \hat{z}\frac{\partial V}{\partial z}$$

$$\nabla \cdot \vec{A} = \frac{\partial A_x}{\partial x} + \frac{\partial A_y}{\partial y} + \frac{\partial A_z}{\partial z}$$

$$\nabla \times \vec{A} = \begin{vmatrix} \hat{x} & \hat{y} & \hat{z} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ A_x & A_y & A_z \end{vmatrix} = \hat{x}\left(\frac{\partial A_z}{\partial y} - \frac{\partial A_y}{\partial z}\right) + \hat{y}\left(\frac{\partial A_x}{\partial z} - \frac{\partial A_z}{\partial x}\right) + \hat{z}\left(\frac{\partial A_y}{\partial x} - \frac{\partial A_x}{\partial y}\right)$$

$$\nabla^2 V = \frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2} + \frac{\partial^2 V}{\partial z^2}$$

Cylindrical coordinate (r, ϕ, z)

$$\nabla V = \hat{r}\frac{\partial V}{\partial r} + \hat{\phi}\frac{1}{r}\frac{\partial V}{\partial \phi} + \hat{z}\frac{\partial V}{\partial z}$$

$$\nabla \cdot \vec{A} = \frac{1}{r}\frac{\partial}{\partial r}(rA_r) + \frac{1}{r}\frac{\partial A_\phi}{\partial \phi} + \frac{\partial A_z}{\partial z}$$

$$\nabla \times \vec{A} = \frac{1}{r}\begin{vmatrix} \hat{r} & \hat{\phi}r & \hat{z} \\ \frac{\partial}{\partial r} & \frac{\partial}{\partial \phi} & \frac{\partial}{\partial z} \\ A_r & rA_\phi & A_z \end{vmatrix} = \hat{r}\left(\frac{1}{r}\frac{\partial A_z}{\partial \phi} - \frac{\partial A_\phi}{\partial z}\right) + \hat{\phi}\left(\frac{\partial A_r}{\partial z} - \frac{\partial A_z}{\partial r}\right) + \hat{z}\frac{1}{r}\left[\frac{\partial}{\partial r}(rA_\phi) - \frac{\partial A_r}{\partial \phi}\right]$$

$$\nabla^2 V = \frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial V}{\partial r}\right) + \frac{1}{r^2}\frac{\partial^2 V}{\partial \phi^2} + \frac{\partial^2 V}{\partial z^2}$$

Spherical coordinate (R, θ, ϕ)

$$\nabla V = \hat{R}\frac{\partial V}{\partial R} + \hat{\theta}\frac{1}{R}\frac{\partial V}{\partial \theta} + \hat{\phi}\frac{1}{R\sin\theta}\frac{\partial V}{\partial \phi}$$

$$\nabla \cdot \vec{A} = \frac{1}{R^2}\frac{\partial}{\partial R}(R^2 A_R) + \frac{1}{R\sin\theta}\frac{\partial}{\partial \theta}(A_\theta \sin\theta) + \frac{1}{R\sin\theta}\frac{\partial A_\phi}{\partial \phi}$$

$$\nabla \times \vec{A} = \frac{1}{R^2\sin\theta}\begin{vmatrix} \hat{R} & \hat{\theta}R & \hat{\phi}R\sin\theta \\ \frac{\partial}{\partial R} & \frac{\partial}{\partial \theta} & \frac{\partial}{\partial \phi} \\ A_R & RA_\theta & (R\sin\theta)A_\phi \end{vmatrix}$$

$$= \hat{R}\frac{1}{R\sin\theta}\left[\frac{\partial}{\partial \theta}(A_\phi \sin\theta) - \frac{\partial A_\theta}{\partial \phi}\right] + \hat{\theta}\frac{1}{R}\left[\frac{1}{\sin\theta}\frac{\partial A_R}{\partial \phi} - \frac{\partial}{\partial R}(RA_\phi)\right] + \hat{\phi}\frac{1}{R}\left[\frac{\partial}{\partial R}(RA_\theta) - \frac{\partial A_R}{\partial \theta}\right]$$

$$\nabla^2 V = \frac{1}{R^2}\frac{\partial}{\partial R}\left(R^2\frac{\partial V}{\partial R}\right) + \frac{1}{R^2\sin\theta}\frac{\partial}{\partial \theta}\left(\sin\theta\frac{\partial V}{\partial \theta}\right) + \frac{1}{R^2\sin^2\theta}\frac{\partial^2 V}{\partial \phi^2}$$

Appendix C: Table of Integrals

$$\int \sin^2\theta d\theta = \frac{\theta}{2} - \frac{1}{4}\sin 2\theta + \text{constant}$$

$$\int \cos^2\theta d\theta = \frac{\theta}{2} + \frac{1}{4}\sin 2\theta + \text{constant}$$

$$\int \sin\theta\cos^2\theta d\theta = -\frac{1}{3}\cos^3\theta + \text{constant}$$

$$\int \cos\theta\sin^4\theta d\theta = \frac{1}{5}\sin^5\theta + \text{constant}$$

$$\int \sin 2\theta d\theta = -\frac{1}{2}\cos 2\theta + \text{constant}$$

$$\int x\sqrt{a^2 - x^2}\, dx = -\frac{1}{3}\left(a^2 - x^2\right)^{3/2} + \text{constant}$$

$$\int \sqrt{a^2 - x^2}\, dx = \frac{x}{2}\sqrt{a^2 - x^2} + \frac{a^2}{2}\tan^{-1}\left(\frac{x}{\sqrt{a^2 - x^2}}\right) + \text{constant}$$

$$\int \frac{x}{\sqrt{a^2 - x^2}} dx = -\sqrt{a^2 - x^2} + \text{constant}$$

$$\int \frac{dz}{\left(r^2 + z^2\right)^{3/2}} = \frac{z}{r^2\sqrt{r^2 + z^2}} + \text{constant}$$

$$\int \frac{rdr}{\left(r^2 + z^2\right)^{3/2}} = \frac{-1}{\sqrt{r^2 + z^2}} + \text{constant}$$

$$\int \frac{dx}{a^2 + x^2} = \frac{1}{a}\tan^{-1}\left(\frac{x}{a}\right) + \text{constant}$$

End Of Paper